

THE WORLD OF CHEMISTRY

Program #25

CHEMISTRY AND THE ENVIRONMENT

Producer Robert Kaper

Air Script: October 31, 1988

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Annenberg/CPB Project Logo and Music

Funder Credits

MONTAGE: Chemical plants,
microorganisms, pollution,
chemical waste dump, lake

NARRATOR (NAT SOUND under):
Chemicals. From industrial plants, as
from living cells, all molecules have to
go somewhere. And just as that has been
a problem for cities and for ordinary
householders, so has it been a problem
for industry. Chemical waste provides a
challenge for both society and science, a
challenge to be met by understanding
chemistry and the environment.

SUPER: CHEMISTRY AND
THE ENVIRONMENT

THE WORLD OF CHEMISTRY OPEN: Montage, Music, Logo

RH next to water

ROALD HOFFMANN (SYNC):

We've seen in the last program that our bodies are intricate chemical factories. They take in molecules, they break them down, and then reshape them into still more complex ones. And in our bodies all kinds of ingenious cycles shuttle around molecules and energy. But we are not closed systems. We take in things and we put out molecules. The planet that we live on is, however, a reasonably closed system. It has those marvelous cycles of carbon dioxide, of water, of sulfur, of other elements and compounds, and we are part of those cycles. It would be fine if the earth had to deal only with our bodies, but we also make tools, and not only hammers, but cars, and chemical factories, and power plants. And these tools magnify our actions, and as we use them to better the way that we live, we sometimes discard into the environment something, or a lot of it. What we dump or spill, however we foul our nest may hurt us. It may hurt other species. It may interfere with those grand cycles. In this program, we will look at how we and our tools affect the earth, how chemistry gives us the ability to assess what we do, and we will look at some possible solutions.

MONTAGE: Pollution, shots of nature, fungi and bacteria, clouds, lakes and forests

NARRATOR (MUSIC and NAT SOUND under):

Recycling. We're turning to it more and more as a way to get rid of waste. Though it may sound new, recycling has been going on in nature for billions of years. Plants absorb waste carbon dioxide that animals exhale. Animals eat plants and breathe the oxygen plants give off. Animal wastes return to the earth. Sooner or later, animals themselves return to the earth. There, fungi and bacteria break them down into simpler compounds that are absorbed, again, by plants. And the cycle continues. Life is a complex web of chemical cycles, sets of balanced reactions ultimately powered by sunlight. The whole earth makes up a giant bank of chemical compounds. Until humans appeared, withdrawals and deposits stayed more or less in balance. But that balance can be tipped. Carbon dioxide is a vital plant nutrient. Without it, life couldn't exist. But humans are producing too much of it, by burning coal and oil. Cutting down forests adds to the problem. Trees that could absorb the excess CO₂ are gone. More and more carbon dioxide traps more and more heat, the greenhouse effect. Ultimately, there may be too much of it for nature to recycle. (cont.)

NARRATOR cont:

Natural recycling is also affected when we add to the environment new synthetic molecules. Nature has not had time to evolve fungi and bacteria to break them down. Dr. Peter Raven is a member of the National Academy of Sciences.

INTERVIEW: Dr. Peter
Raven, National Academy
of Sciences

SUPER: Peter Raven

DR. PETER RAVEN (SYNC):

Obviously, it's more and more apparent that the world is not an endless sink or an endless disposal area for things that we manufacture. But equally obviously, we're gonna go on manufacturing things for our own benefit. What we need to do is measure the benefits and the, and the disadvantages of manufacturing those, decide what we're doing with them and how we're disposing of them, on a case-by-case basis.

MONTAGE: Spraying DDT,
dead fish and birds, rain,
microorganisms, nature
shots, PCBs in use,
analyzing PCBs,
pollution

NARRATOR (NAT SOUND under):

In some cases, we've started to do that. DDT was once used worldwide to kill insects. (cont.)

NARRATOR cont:

It probably saved hundreds of thousands of lives from insect-borne diseases like malaria. Today, DDT is banned in most western countries, because it also killed fish, and nearly wiped out several types of birds. It interfered with the formation of their egg shells, causing many to break in the nest. Rain washed the DDT into the water. Algae and other microorganisms absorbed it. Larger creatures that fed on the algae accumulated the chemical in their bodies. Fish-eating birds were at the top of the food chain, and they accumulated the most. PCBs, polychlorinated biphenols, another group of environmentally persistent chemicals now banned in most countries. They're oily liquids that make a good coolant and insulator for large electrical transformers and capacitors. Like DDT, PCBs have stable carbon-chlorine bonds, and like DDT, they're nonpolar, so they dissolve and accumulate preferentially in body fat. We've banned DDT and PCBs, but there are other pollutants that still cause concern. Are we concerned about these forms of pollution just for the sake of a few endangered species? Or is there a more compelling reason?

INTERVIEW: Dr. Peter
Raven cont.

DR. PETER RAVEN (SYNC):

Well, by and large, pollution damages biological productivity of one kind or another, and human existence is largely based on biological productivity.

Agricultural productivity is one obvious example, and there's productivity of forest, of forests for timber, for fuel. Forests are the source of fuel for 1.5 billion of the world's population.

There's productivity of the oceans, there's productivity of lakes. Now, all of these forms of productivity can be altered, limited, or shut down by pollution from chemical and industrial processes.

MONTAGE: Chemical plant,
hazardous waste sites,
pollution

NARRATOR (NAT SOUND under):

Chemical and industrial pollution. It's a controversial subject, particularly when it comes to hazardous waste. Leaking drums, storage tanks, thick chemical sludge. The threat of pollution and illness from hazardous waste has spurred a major government cleanup effort, the Superfund program. It was signed into law in 1980, with total funding eventually nearing \$10 billion. (cont.)

NARRATOR cont:

The Environmental Protection Agency expects to clean up several thousand hazardous sites under Superfund. Yet there's still controversy about just how dangerous they really are. The originator of the test for determining whether a chemical has the potential to cause cancer is Dr. Bruce Ames, biochemist at the University of California, Berkeley.

INTERVIEW: Dr. Bruce Ames, biochemist, University of California, Berkeley

SUPER: Bruce Ames

DR. BRUCE AMES (SYNC):

People have been very worried about toxic waste dumps but, in fact, the evidence that they're really causing any harm is really minimal, there's not very much evidence. And the levels of chemicals are very tiny, so we don't really know whether there's no hazard or a little bit of hazard.

French Ltd. dump site, shots of town, church and parishioners

NARRATOR (NAT SOUND under):

Texas Bayou country, just east of Houston. Sand-mining operations have left open pits in the swampy ground. They made convenient dump sites for hazardous wastes from oil refineries and chemical plants. (cont.)

NARRATOR cont:

The French Limited dump site holds nearly 140,000 cubic yards of toxic sludge and contaminated soil, metal finishing acids, benzene, PCBs. The site is now part of the Superfund program, and work is going ahead to clean it up. But in nearby towns, there's concern over the dump's health effects, although many experts feel there's no danger. These opposing views illustrate the poor communication between scientists and the public. Inside St. Martin de Porres Catholic Church, parishioners' opinions show how public fears can outrun scientific fact.

INTERVIEWS: Church
parishioners

PARISHIONER (SYNC):

Definitely we have problems. We have people, we have at least 13 people that I know of that died of cancer since this dump has been there. And you didn't have that before. When we were little children, our people didn't die with cancer. They just died of old age, a hundred and six years old, or somebody killed them or they got killed in a car wreck. Everything now in Barrett Station is cancer. You better not go to a doctor if you don't want to hear it's cancer.

PARISHIONER (SYNC):

So it's got to affect the people, because special, you know, when the wind is blowing from the west, or the people in this end gets it real bad. And quite natural, when your wind change direction, well, the other people, you know, wherever the wind be blowing, they gets it. And it's just I don't think it's healthy. I know it's not.

PARISHIONER (SYNC):

I be short-winded, I done have four surgeries, one for cancer. I done have a spot on my lungs. I had pneumonia every year. So I don't know what the cause of it.

NARRATOR (NAT SOUND under):

The fears of those exposed to hazardous wastes may not be realistic, but they are real. Dr. Halina Brown is a Professor of Toxicology at Clark University.

INTERVIEW: Dr. Halina Brown, Professor of Toxicology, Clark University

SUPER: Halina Brown

DR. HALINA BROWN (SYNC/VO):

What is the disease that we are talking about? Cancer, dreadful disease, disease that everybody fears. What if that risk of one in ten thousand means that it's my child is going to get sick? (cont.)

DR. HALINA BROWN cont:

It's not enough abstract concept anymore, it's an extremely personal concept.

Shots of church parishioners

There is a tremendous gap between how people who are affected by the exposure to this environment and carcinogens perceive the risk and how a scientist would perceive the risk.

Shots of chemists working in labs, hazardous waste site

NARRATOR (NAT SOUND under):

How do scientists perceive the risk from chemicals and the environment? Most chemicals, even vitamins, can be toxic at large doses. Most chemicals, in fact, have a threshold dose of toxicity. A dose above the threshold is dangerous, a dose below it is not. But there's a great deal of debate over whether potential carcinogens have such thresholds, that is, concentrations below which they won't cause cancer. Given conflicting and imprecise evidence, some scientists talk about carcinogens in terms of risk or probabilities. Risk is relative. For example, some think the cancer risk from hazardous waste is negligible compared to the naturally occurring carcinogens we successfully resist every day.

INTERVIEW: Dr. Bruce
Ames cont.

DR. BRUCE AMES (SYNC):

The world is full of carcinogens, because half the natural chemicals they've tested have come out as carcinogens. Some plants have toxic chemicals to keep off insects, and we are eating those every time we eat a tomato or potato. And mushrooms have carcinogens, celery has carcinogens, an apple has formaldehyde in it. So there are an incredible number of carcinogens in nature; we're getting much more of those than man-made chemicals.

INTERVIEW: Dr. Halina
Brown cont., hazardous
waste sites

DR. HALINA BROWN (SYNC/VO):

If we accept those risks, why can't we accept small risks from chemical carcinogens in the environment? It's a valid argument. But then there is, of course, the counter argument. The counter argument is we cannot do much about trace amount of carcinogens that are present in food, why should we add to this burden that we already have by increasing the amount of exposure to carcinogens. But then it boils down to money. Unfortunately, it takes tremendous resources to reduce the levels of exposure in the environment to carcinogens, especially when you get to very low levels. (cont.)

DR. HALINA BROWN cont:

Reducing it by another order of magnitude may take millions of dollars at one hazardous waste site. And the pie is not unlimited.

Pollution

NARRATOR:

Even those who don't consider hazardous waste dumps a health threat think the money should be spent to clean them up.

INTERVIEW: Dr. Bruce Ames cont.

DR. BRUCE AMES (SYNC):

I mean if Congress has put ten billion dollars for cleaning up toxic waste dumps, you might as well find the worst ones and clean them up. Now, whether you're getting anything -- whether it's really a public health -- you're gaining much in public health for cleaning them up is a matter one could argue about. I think probably very little. But, in any case, you can -- you might as well spend the money cleaning up the worst dumps.

Hazardous waste site and cleanup operation

NARRATOR (NAT SOUND under):

Toxic waste cleanup. Why is it so expensive? One reason is the huge amounts of material that have to be handled. A dump may cover many acres and extend 15 to 20 feet deep. (cont.)

NARRATOR cont:

Another reason is the degree to which the dump must be cleaned up.

Contaminants in water and soil may have to be reduced to several parts per million, and that can require intensive treatment of millions of gallons of water and hundreds of thousands of cubic yards of contaminated sludge and soil. The first step is to remove leaking drums, tanks, and other containers that are contaminating the site. The next stage is the hard part, treating the remaining chemical sludge and removing the contaminants from the soil and water. Several methods are available.

Hazardous waste site, cleanup
operation and analysis

NARRATOR (MUSIC under):

Most involve chemistry. One technique is incineration. Chemicals are burned at high temperatures to oxidize them completely. Carbon dioxide and water vapor go out the stack. Hazardous waste incinerators are often equipped with devices called scrubbers. They trap harmful substances in the exhaust gases, such as metals and chlorine compounds. A close imitation of nature's own recycling is the use of bacteria to break down chemicals. (cont.)

NARRATOR cont:

It's called biodegradation, or bioremediation. Many synthetic compounds cannot be degraded by bacteria, but there are always a few bacteria at a waste dump that can metabolize the complex organic molecules found there. Scientists cultivate these bacteria in the laboratory. They are fed only the toxic chemicals in the dump. Those that can digest the chemicals will prosper; those that can't will die out. It's evolution in fast forward. The survivors are thrown back into the waste dump, where they go to work. This technique is being tested on a full scale at the French Limited chemical dump. At the bottom of the shallow lagoon is a thick sludge of toxic chemicals. Floating compressors pump air into the water to help the bacteria oxidize the wastes. To make it easier for the bacteria to get at the chemicals, the sludge is stirred up with a dredge. The black foam looks awful, but it's actually a good sign, like the head on beer. It's made by enzymes which the bacteria produce to break down the chemicals.

Hazardous waste cleanup
and analysis

NARRATOR (NAT SOUND under):

While cleanup continues, so does monitoring. The untreated sludge is sampled to determine what chemicals it contains. Samples taken from the core are sent to a laboratory for chemical analysis. Lab tests identify the specific compounds present and their concentrations. Other monitoring at the site includes checks for chemicals escaping from the lagoon either by leaking into the ground or evaporating into the air. Escaping gases are measured at the edge of the lagoon and at selected locations in the surrounding area. Ground water is sampled through pipe wells sunk at several locations around the pit. The pipes extend to different depths. Chemical analysis of the water sample reveals how far contamination has spread outward and downward from the dump. Eventually, the bacteria will break down all the organic chemicals to harmless concentrations. The water will then be pumped out of the lagoon and discharged, and the pit will be filled in. Four years of work and fifty million dollars later, one chemical waste dump will be history.

Exxon Chemical: plant shots

NARRATOR (MUSIC and NAT
SOUND under):

Baytown, Texas, home of a giant Exxon chemical complex, third largest in the world. Nationwide, cleanup is under way, yet industry will always produce chemical wastes. They are an integral part of manufacturing process. Today, however, much is being done to minimize those wastes and their effect on the environment. Exxon makes several different chemical products here, including polypropylene plastic. The company is engaged in a major waste reduction program in order to meet today's stricter environmental regulations and to save money. Chemical waste is money down the drain, or up the stack. So good environmental practices are also good business. Charles Seay is Environmental Manager for Exxon Chemical.

INTERVIEW: Charles Seay,
Environmental Manager,
Exxon Chemical

SUPER: Charles Seay

CHARLES SEAY (SYNC):

When we look at waste management, our first priority is to reduce the generation of waste, and then we look at recycle and treatment next, and disposal only as a last resort.

Exxon Chemical: plant shots,
waste analysis

NARRATOR (NAT SOUND under):
Reducing the generation of waste takes many forms, but one very simple and effective technique is regularly checking for leaks into the air from the plant's thousands of valves. Leaking gas is drawn into a measuring instrument. A catalyst inside oxidizes it. The amount of heat produced is a measure of the hydrocarbon concentration. Tightening the packing around the valve stem usually stops the leak. If not, a maintenance crew will repair it. All valves in the plant are numbered. They're entered into a computer to keep track of their leak status. The system helps control the thousands of tiny gas emission sources that could otherwise be overlooked.

INTERVIEW: Charles
Seay cont.

CHARLES SEAY (SYNC):
It doesn't appear to be much in any particular single valve or instance, but in aggregate it represents a significant quantity.

Exxon Chemical: plant shots

NARRATOR (NAT SOUND under):
But waste production can only be reduced so far. There's always going to be a certain amount of unwanted by-product that has to go somewhere.

INTERVIEW: Charles
Seay cont.

CHARLES SEAY (SYNC):

We've learned to recycle and recover many of our waste streams in the form of energy, to use them as fuel. And we've also learned to look at other product applications for some of these wastes.

Exxon Chemical: plant shots

NARRATOR (NAT SOUND under):

An example is the main by-product of polypropylene manufacture. It consists of branched chain molecules instead of the straight chain polypropylene that makes up the white plastic product. At present, it's burned as a fuel. But the company hopes to convert it to a putty-like plastic that can be sold as weather stripping and window sealer. Even straight chain polypropylene beads are considered waste if they're the wrong size or shape. So to eliminate the cost of disposal, the company recovers them from the plant waste water system for sale. Buyers are companies that don't need high quality plastic, such as toy manufacturers. The waste water collection system picks up spills and chemical leaks from all plant operations. As much waste as possible is separated from the water and recycled. Oil can be skimmed off and used as fuel. (cont.)

NARRATOR cont:

The dirty water remaining is decontaminated with bacteria in a waste water treatment plant. It's basically the same treatment given to chemical waste dumps in bioremediation. Chemicals in waste water are costly to the company in two ways: useful materials are wasted, and it costs money to remove them from the water. So the water from each separate plant operation is sampled daily to keep track of discharged chemicals. Chemists will analyze the water in the laboratory to determine how much waste it contains, and the operation that produced the waste will be charged for the cost of treating it. The same principle applies to solid waste and sludges that have to be trucked off site for disposal. Those that can't be recycled or broken down biologically are disposed of in pits lined with heavy plastic or clay to prevent leakage. It's an expensive way to dump garbage, but for this industry, it's worth it.

INTERVIEW: Charles
Seay cont.

CHARLES SEAY (SYNC):

Clearly the rapid escalation of disposal cost has provided an increased incentive to become more effective at reducing waste. (cont.)

CHARLES SEAY cont:

You know, I think it's -- we've seen increases of 15 percent or more a year for some length of time, and there's no reason to assume that they won't continue to escalate, looking ahead to the future.

MONTAGE: Pollution,
hazardous waste sites,
church parishioners,
plant shots

NARRATOR (MUSIC under):

Chemical waste, then, and its effect on the environment, can be minimized both economically and safely, and the polluting dumps of the past are being gradually eradicated. How can people be reassured that technological and economic progress will not harm the environment or health? Through more accurate and open public communication, and through improvements in the science and management of waste disposal.

Chemistry has brought enormous benefits to the largest numbers of people. Sometimes it has brought problems, problems that, in turn, can be understood and resolved through chemistry. To maximize living standards and life expectancy in the future, industrial and environmental planning must go hand in hand.

INTERVIEW: Dr. Bruce
Ames cont.

DR. BRUCE AMES (SYNC):
Chemical companies are making all these useful chemicals and plastics that we need in our lives, and weren't worrying too much about where they were dumping their waste products, and then people realize, well, Lake Erie gets polluted, and then we started making rules. And so I think we've done really quite well. The U.S. is probably the least polluted country in the world, when you look at it. And it's again a question of learning new things and adapting to them, and the country has done that very well.

INTERVIEW: Dr. Peter
Raven cont.

DR. PETER RAVEN (SYNC):
We're not really willing to do away with the industrial processes, so what we need to decide is how much disruption of the atmosphere we're willing to tolerate, what the atmosphere can absorb, what the atmosphere can't absorb, and then decide on a kind of a collective compromise. The operational point, though, I think is that human beings are already running the whole global ecosystem very intensively, and we need then to make choices between degrees of management and make them sensibly and on a global basis.

Credits, Closing Montage, Closing Music

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